N73-26066
CR-133202

SCIENTIFIC AND TECHNICAL SERVICES
DIRECTED TOWARD THE DEVELOPMENT OF
PLANETARY QUARANTINE MEASURES FOR AUTOMATED SPACECRAFT

First Quarterly Report

Contract NASw-2503

For

National Aeronautics and Space Administration
Planetary Quarantine Office
Washington, D. C. 20546

July 1973

by

EXOTECH SYSTEMS, INC.
5205 Leesburg Pike
Falls Church, Virginia 22041

Table Of Contents

		Page
1.0	INTRODUCTION	1
2.0	TASK PROGRESS	1
2.1	Task 1. Evaluation of the Impact of Changes in Planetary Quarantine Requirements	1
2.2	Task 2. Maintain and Operate the Planetary Quarantine Document System	2
2.3	Task 3. Microbial Contamination Logs	3
2.4	Task 4. Maintenance of Allocation Bank	3
2.5	Task 5. Creation and Maintenance of List of Approved Parameters	4
2.6	Task 6. Preparation of Technical Information Memo	4
2.7	Task 7. Evaluation of Flight Project Quarantine Plans	5
2.8	Task 8. Supporting Analysis of Planetary Quarantine Sterilization Parameters	5
2.9	Task 9. Preparation of Technical Presentations	6
2.10	Task 10. Technical Support at Meetings	6
2.11	Task 11. Support of Technology Transfer	7
2.12	Task 12. Integrated Resumes of NASA Research	7
3.0	ANALYSIS	8
3.1	P(st) Analysis	8
3.2	Early Teflon Strip Experiment Analysis	24

SCIENTIFIC AND TECHNICAL SERVICES
DIRECTED TOWARD THE DEVELOPMENT OF
PLANETARY QUARANTINE MEASURES FOR AUTOMATED SPACECRAFT

1.0 INTRODUCTION

This report constitutes the First Quarterly Progress Report summarizing work performed through June 30, 1973 under contract NASw-2503.

The material is organized in two parts; viz., a section describing the work performed on each of the twelve tasks and an analysis section presenting details on two analytical studies performed during the reporting period.

2.0 TASK PROGRESS

Progress during the reporting period is described in this section for the twelve contract specified tasks.

2.1 Task 1. Evaluation of the Impact of Changes in Planetary Quarantine Requirements

Under this task, evaluations are conducted to support the justification and establishment of planetary quarantine requirements and parameters and to estimate their implications upon flight projects.

During this reporting period the following parameters were reviewed:

- D values
- $P_S(r)$ for surface burden
- P (g) for outer planets
- P(N) for Saturn missions
- P (st) for surviving space travel

D Values — The effect of inactivation characteristics on D values to be used in establishing sterilization cycles was assessed using data from investigations of the heat inactivation of teflon strip fall out burdens with wild organisms. The tests were conducted by Dr. M. Favero and Mr. R. Puleo of CDC and Mr. M. Wardle of JPL. This work is described in Section 3.2.

$P_S(r)$ — The possibility of a change in the value of $P_S(r)$ as a result of the work of Mr. M. Chatigny of NBRL, and others engaged in surface release studies, is being reviewed to determine if the current specification (which is recognized to be conservative) can be reduced.

P (g) — Values for the probability of growth are needed for Saturn and other outer planets to facilitate advanced mission planning. Pertinent PQO-sponsored research, conducted principally by the JPL, and related space studies by others were reviewed in developing a range of possible values for this parameter.

P(N) — A value for P(N), the allowable probability of contamination, for the Saturn leg of the Pioneer G Mission option was developed using an allocation scheme similar to that employed for Mars, Venus and Jupiter. The recommended value of 1×10^{-4} for Saturn and for its satellites has been tentatively approved by the PQO.

P(st) — At the request of the PQO, a review was made of research relating to microbial lethality of space vacuum-temperature based upon data previously presented to the PQP, new data from JPL tests and from pertinent literature. The work is described in Section 3.1 of this report.

2.2 Task 2. Maintain and Operate the Planetary Quarantine Document System

The Quarantine Document System (QDS) is an indexed file of material pertinent to the review of flight project quarantine plans and operations.

This task covers the operation, maintenance and updating of the system. It requires the application of techniques for source identification, acquisition criteria, cataloguing and indexing, and responsive retrieval.

During the reporting period the collection experienced continued growth and use. The collection now numbers 580 documents. Many

retrievals were requested by PQO and ESI staff members in support of such activities as the NASA Life Sciences Committee's review of the Planetary Quarantine Program, the Viking Project Bioassay Program, the preparation of materials for presentation at COSPAR, PQP and at the Spacecraft Sterilization Seminar and of the review of parameter specifications, e.g. Task 1.

2.3 Task 3. Microbial Contamination Logs

The Committee on Space Research (COSPAR) has asked each launching nation to supply it with information on all planetary missions that will permit the maintenance of a contamination log. For record purposes and to establish the allocation of contamination probabilities to future missions to planets of biological interest, the Planetary Quarantine Officer requires a log of missions of all nations insofar as data are available. This task supports the preparation and maintenance of these logs.

Pertinent information regarding recent flights was compiled and used to update logs for the planets Mars, Venus and Jupiter. Copies of these logs were submitted to the PQO for delivery at the COSPAR meeting in May at Konstanz, FRG.

As additional flight data become available from Pioneer 10, 11 and Mariner 9, these logs will be updated. Summarizations will be noted on the PQ Status Board.

2.4 Task 4. Maintenance of Allocation Bank

The United States, the Union of Soviet Socialist Republics and other launching nations are allotted portions of the total probability of contamination of each planet and provided with estimates of the total number of missions expected to be flown. From these data, the Planetary Quarantine Officer makes pre-launch allocations of the probability of contamination that may be used by each flight project. The purpose of this task is to assist the Planetary Quarantine Officer in making the optimum allocation, consistent with NASA and COSPAR policies, to each United States mission.

During this reporting period an allocation scheme was applied to Saturn in developing a P(N) value for the Saturn encounter option of the Pioneer G mission, as reported under Task 1.

Reports of the Mariner 9, Pioneer 10 and Pioneer 11 flights are being monitored for possible effects on the allocation banks for the respective planets. Changes are being reflected on the PQ Status Board at NASA as they occur.

2.5 Task 5. Creation and Maintenance of List of Approved Parameters

Uniformity of policy and facilitation of document review can be effected through a listing of parameters and requirements employed by flight projects in validating compliance with basic PQ constraints. This task covers the preparation of such a listing with definitions, references to pertinent research, and approved numerical values or ranges.

In order to ensure the availability of timely, accurate and updated PQ parameter data to each flight project, mission planning group and to others envolved in space research, a method for the systematic dissemination of these data is being developed. A controlled-distribution book of specification sheets with provisions for rapid revision and orderly incorporation of additions is being prepared for review and approval by the PQO.

Preliminary specifications of parameters defining some of the PQ requirements currently imposed upon U.S. space flight missions were unofficially documented and assembled into reduced-size documents for distribution to COSPAR meeting participants to illustrate the U.S. Planetary Quarantine Program compliance management methodology and practice.

2.6 Task 6. Preparation of Technical Information Memo

The Planetary Quarantine Technical Information Memo (TIM) is a brief, informal newsletter containing summaries of research results of note, meetings, significant travel plans, policy decisions, changes in personnel, initiation of new research tasks, and management deadlines. It is submitted to approximately 100 people involved in the PQ Program.

The first issue of the new volume in this series is in final preparation stage for distribution in July. Reported items will include the COSPAR Meeting in Konstanz, FGR., and the recently developed book of specification sheets for parameters and requirements related to PQ constraints.

2.7 Task 7. Evaluation of Flight Project Quarantine Plans

This task provides support to the PQO in the review and approval of flight project documentation demonstrating compliance with PQ requirements. The Pioneer 11 Postlaunch Analysis of Compliance with COSPAR Recommendations (Ames Document No. PAL-3-35 (244-8) dated May 7, 1973) was reviewed.

Preliminary drafts of two Viking documents were received during this period and are being reviewed. These are:

- Preliminary Copy, M75-148-0. Viking 75 Program Microbiological Assay and Monitoring Plan

- Preliminary Copy, M75-147-0. Viking 75 Program Lander Capsule Sterilization Plan

A review meeting on these documents is planned for September.

2.8 Task 8. Supporting Analysis of Planetary Quarantine Sterilization Parameters

This task includes analyses and evaluations intended to support the interpretation of research results and to facilitate the quantification of PQ requirements. During the reporting period three (3) assignments were carried out under this task.

- The first assignment reviewed data on lethal effects of space UV and modified the specification sheet for the probability of surviving UV by applying a correction factor to account for the change in UV flux with distance from the Sun.

- The second task, initiated during this quarter, includes reviewing data relating to potential inactivation due to solar radiation and exposure to trapped belt radiation, with particular reference to the value of space survival parameters for martian and outer planet missions. The possibilities of exposure to high intensity fluxes with sufficient energy and duration for effective reduction of surface burden are being investigated. A major portion of the applicable experimental data is the work currently being performed by the JPL.

- A third activity, covered during this quarter, involves analysis of certain new information bearing on the design of sterilization cycles. This activity, in effect, follows from the initial work described in Section 3.2. The new information has been systematically compared to the existing specifications and requirements. This activity will be presented at the July 12, 1973 Denver PQP meeting and reported in the second quarterly report.

2.9 Task 9. Preparation of Technical Presentations

This task relates to the preparation of written and graphic material as required by the PQO for publications, briefings, speeches on PQ subjects and communications to individuals and groups.

During the reporting period the following support was provided under this task:

- Written, visual and taped material documenting the PQ presentation of January 23, 1973 to an Ad Hoc Subcommittee of the Life Sciences Committee. [This activity is partially complete.]

- Visual materials prepared for presentation to the PQP April 1973 at the Kennedy Space Center.

- Final preparation of the presentation at the COSPAR meeting at Konstanz, FRG., May 1973.

- Preparation and reproduction of Contamination Logs for Mars, Venus and Jupiter for delivery at COSPAR.

- Preparation and reproduction of Specification Sheets for U.S. Planetary Quarantine Program for distribution to COSPAR attendees. [Unofficial document prepared specially for COSPAR]

2.10 Task 10. Technical Support at Meetings

The PQO has frequent need for technical support relative to meetings of the LSC, SSB, COSPAR, flight project PQ working groups and

experimenters' conferences. This task covers the provision of this support on request of the PQO and includes the compilation of analytical data, attendance at specified meetings and presentations as requested.

Such support was provided for the following meetings and conferences:

- April 19–20, 1973 — JPL/Exotech Meeting re P(st) and JPL Experimental Data — meeting at Pasadena.
- April 26–27, 1973 — PQAP, Cape Kennedy.
- May 18, 1973 — Washington, D.C. PQO/Langley/ Bionetics/Exotech — Viking PQ Discussions.
- May 29, 1973 — Hampton, Va. — Bionetics/Exotech Viking PQ.
- May 30–31 - June 1, 1973 — Cape Kennedy — Wild Organism Experimental Data.
- June 28, 1973 — Hampton, Va. — PQO/Langley/ Bionetics/Exotech — Viking PQ.

2.11 Task 11. Support of Technology Transfer

This task supports the transfer of PQ technology between Centers, between Centers and Projects, between NASA and its contractors and between NASA and the scientific community. It covers such activities as the preparation of technical presentations and technical support at meetings (subjects of Tasks 9 and 10), as well as the dissemination of PQ technology information upon referral of inquiries by the PQO and the preparation of material for the AIBS PQ Panel.

Requests for PQ information have been received from PQO staff and the GWUBSCP and have been filled by retrievals from the QDS. In addition, assistance was provided in suggesting items for consideration at the PQP meeting scheduled for July 12–13 in Denver.

2.12 Task 12. Integrated Resumes of NASA Research

This task is intended to provide resumes of research combining all relevant data from all sources on a specific subject.

No specific assignments have been made under this task; however, several important research areas have been reviewed and pertinent data compiled or reported verbally. These areas include:

- Effect of heat resistant sub-populations on D value specification
- Lethal stresses of space radiation
- Back contamination and sample return

3.0 ANALYSIS

Two analytical studies were completed during this reporting period. Both related to the possible influence upon parameter quantification of on-going and recently-completed experimental programs. One of these is the heat inactivation of naturally occurring microorganism populations being investigated by the U.S. Public Health Service at Kennedy Space Center. The other is the study of microbial viability under exposure to the simulated space travel stresses of temperature, time and vacuum. Our reviews are presented below.

3.1 P(st) Analysis

Summary

At the request of the PQO, a review was made of:

1) the previous data and presentations which had been made to PQP;
2) the current JPL Vacuum-Temperature Data being prepared by Dr. D. Taylor; and
3) pertinent literature bearing on P(st).

Recommendations, based on the above review and analysis were prepared and presented to PQP on April 26, 1973 at Cape Kennedy, Florida.

Previous P(st) Presentations

The first PQP presentation reviewed was that presented by Dr. J. Stern of Bionetics Corp. during October 1972 at the Atlanta PQP meeting. This presentation reviewed most of the applicable literature. Figure 3.1-1 is typical of the data presented concerning survival of vegetative organisms. Data also was presented on survival of spores under various temperature and time environments. After reviewing the material presented by Dr. Stern it was apparent that the wide spread of data was due, in part, to the fact that the work reviewed included at least three major variables: organism type; test temperature; and, exposure time. Hence, a clear picture of the effects of vacuum and temperature on organism survival really required a matrix of experimental data as illustrated in Figure 3.1-2.

The next prior presentation reviewed was the JPL presentation at New Orleans on January 30 — February 1, 1973 by Dr. Taylor. The data presented is typified by Figures 3.1-3; 3.1-4; 3.1-5; and, 3.1-6. The data in Figures 3.1-5 and 3.1-6, although not so labeled, was only on the spore forming isolates. Study of the JPL presentation indicated: 1) the data was preliminary and had not been reduced; 2) the JPL experiment was very complete and included all elements of the matrix shown in Figure 3.1-2; and, 3) the data could be presented in a three dimensional format for the two variables of time and temperature, as illustrated in Figure 3.1-7.

Coordination with JPL

Review and discussions were held with Dr. D. Taylor to obtain the final reduced data from JPL's computer analysis of these vacuum-temperature data. This data was subsequently presented at the April 26, 1973 PQP presentation at Cape Kennedy by Dr. Taylor.

Literature Review and PQP Presentation of a Proposed P(st)

The appropriate literature was reviewed on the survival of organisms after exposure to various high vacuum-temperature exposures. Figures 3.1-8 and 3.1-9 show two examples of the type of data in the literature. In general, there was a wide range of: 1) organisms; 2) temperatures; 3) exposure times; and, 4) vacuum levels. Hence, exact comparisons were difficult. Figures 3.1-10 and 3.1-11 show plots of all relevant data for spores and vegetative organisms compared to Dr. D. Taylor's data.

Based on all the data reviewed certain general ground rules were stated (Figure 3.1-12) and using these ground rules, and the data presented by Dr. Taylor on April 26, 1973, a proposed approach to a P (st) parameter was prepared and presented to PQP for their consideration (see Figure 3.1-13).

Figure 3.1-1

EFFECT OF TEMPERATURE ON RECOVERY OF VEGETATIVE ORGANISMS

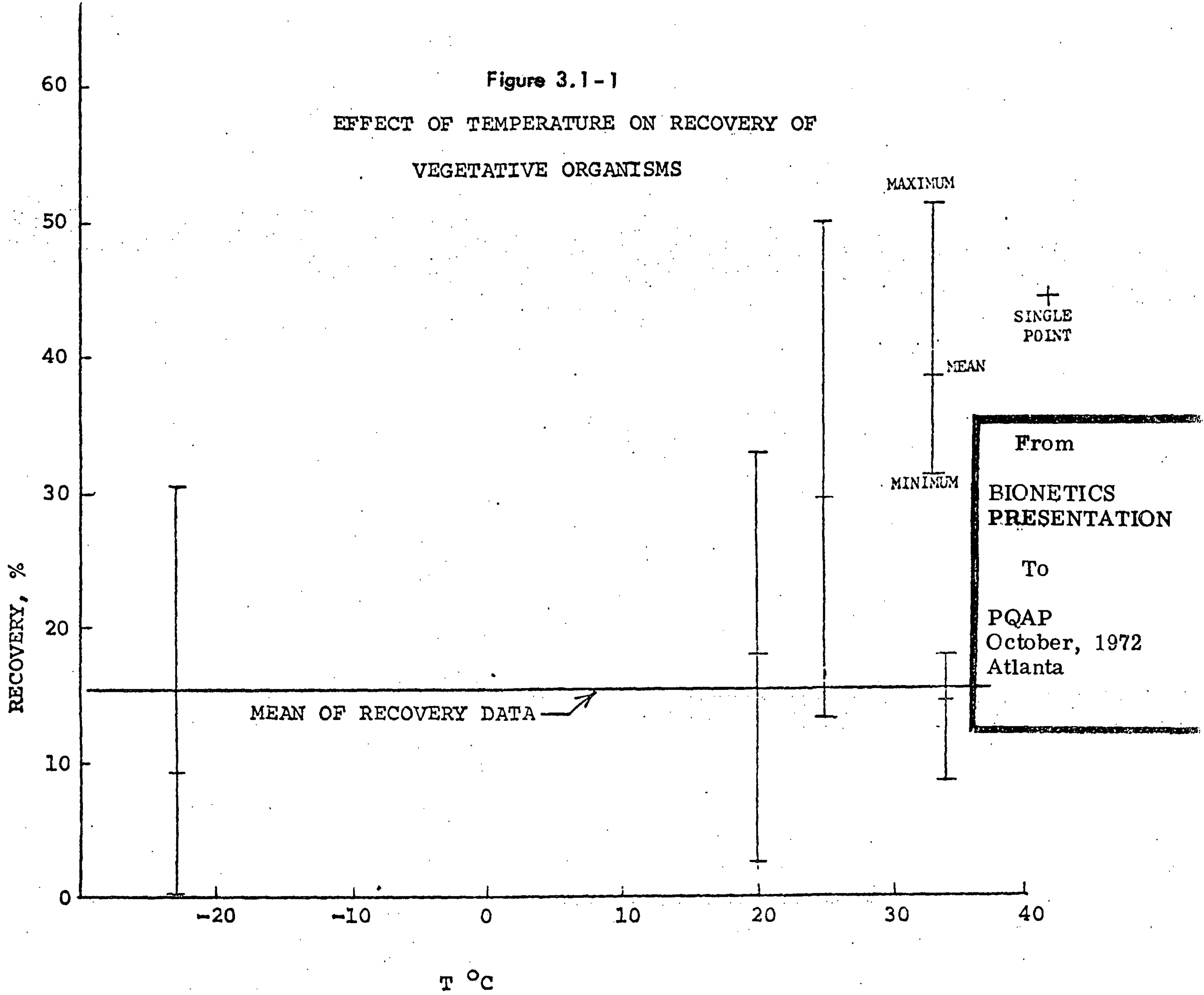


Figure 3.1-2

THE PROBLEM

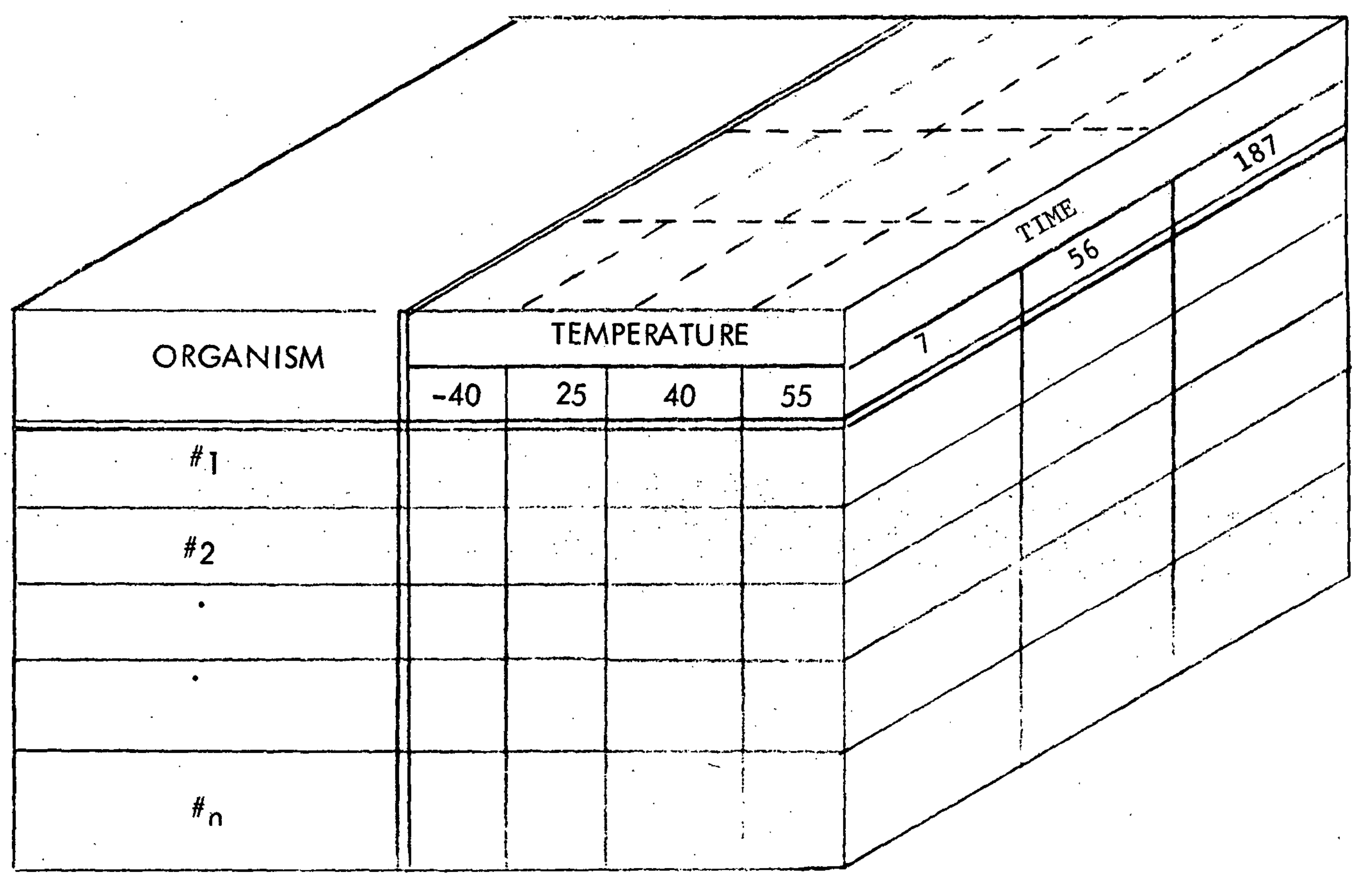
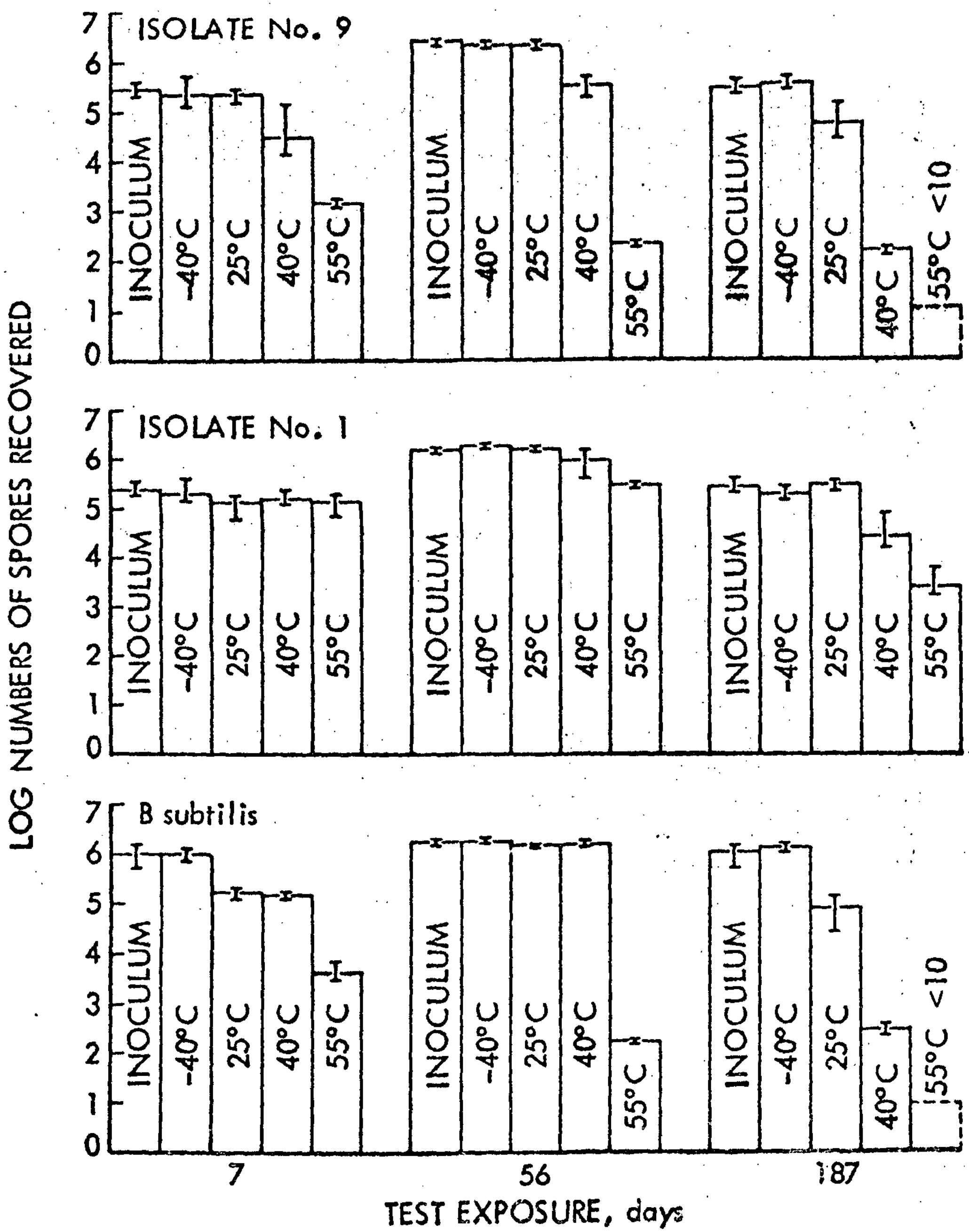


Figure 3.1-3

VACUUM TEMPERATURE RESISTANCE OF SPORES OF SPACECRAFT ISOLATES



New Orleans Semin

January 30/31 197

Figure 3.1-4

DISPERSION VALUES $\left(\frac{\sigma}{\bar{Y}}\right)$

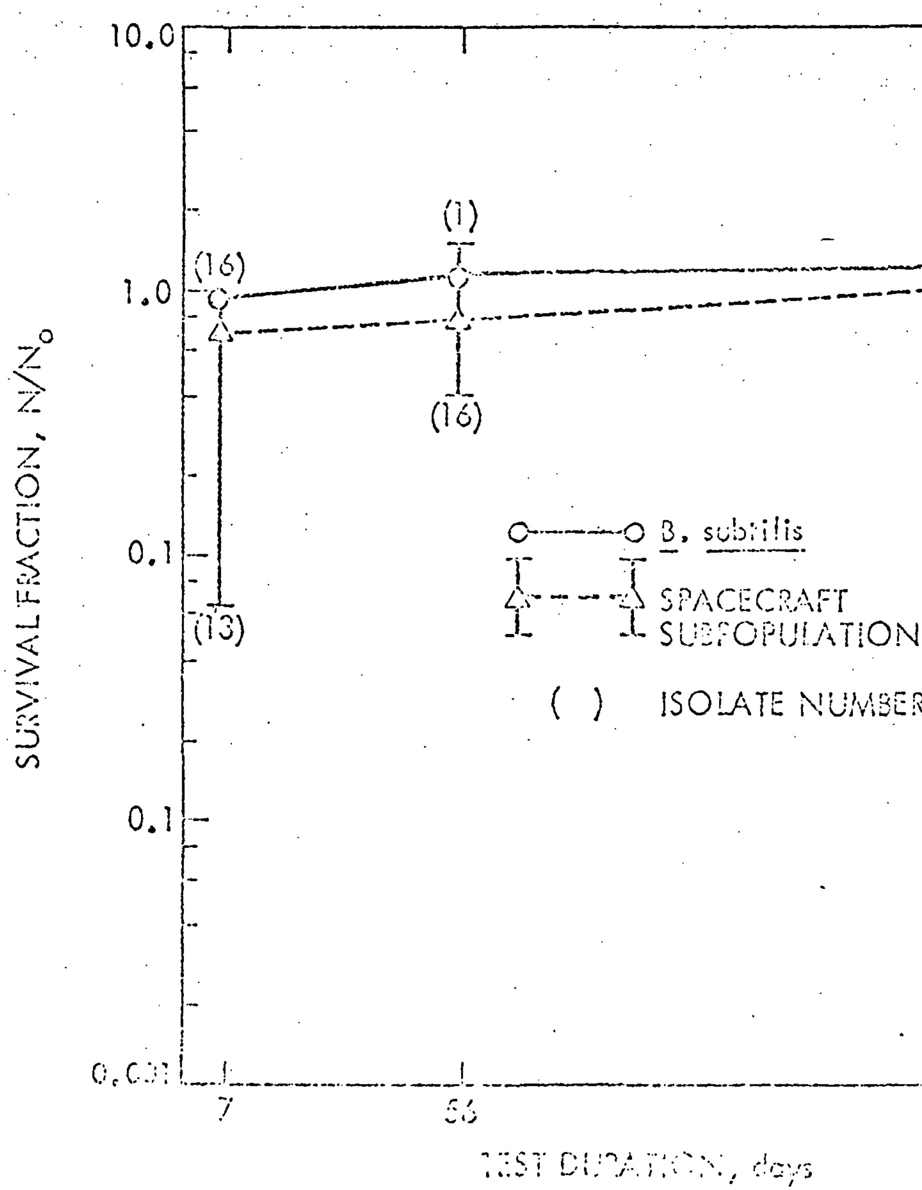
Nonsporeformers

TEMP \ DAYS		7	56	187
No. 4	-40	0.1709	0.0474	0.0100
	+25	0.0582	0.0849	0.0732
	+40	0.1603	0.1731	0.1980
	+55	0.0180	0.3033	0.0982
	t_o	0.1591	0.0768	0.0493
No. 5	-40	0.1272	0.1416	0.0209
	+25	0.0791	0.0613	0.1803
	+40	0.3136	0.0370	0.0632
	+55	0.2304	0.0918	0.0176
	t_o	0.1434	0.0196	0.0040
SE	-40	0.1540	0.0776	0.0801
	+25	0.3277	0.2601	0.0184
	+40	0.1830	0.1652	0.0621
	+55	0.1037	0.0103	0.3471
	t_o	0.0570	0.0350	0.0495

PQAP
New Orleans
Feb.1,1973

Figure 3.1-5

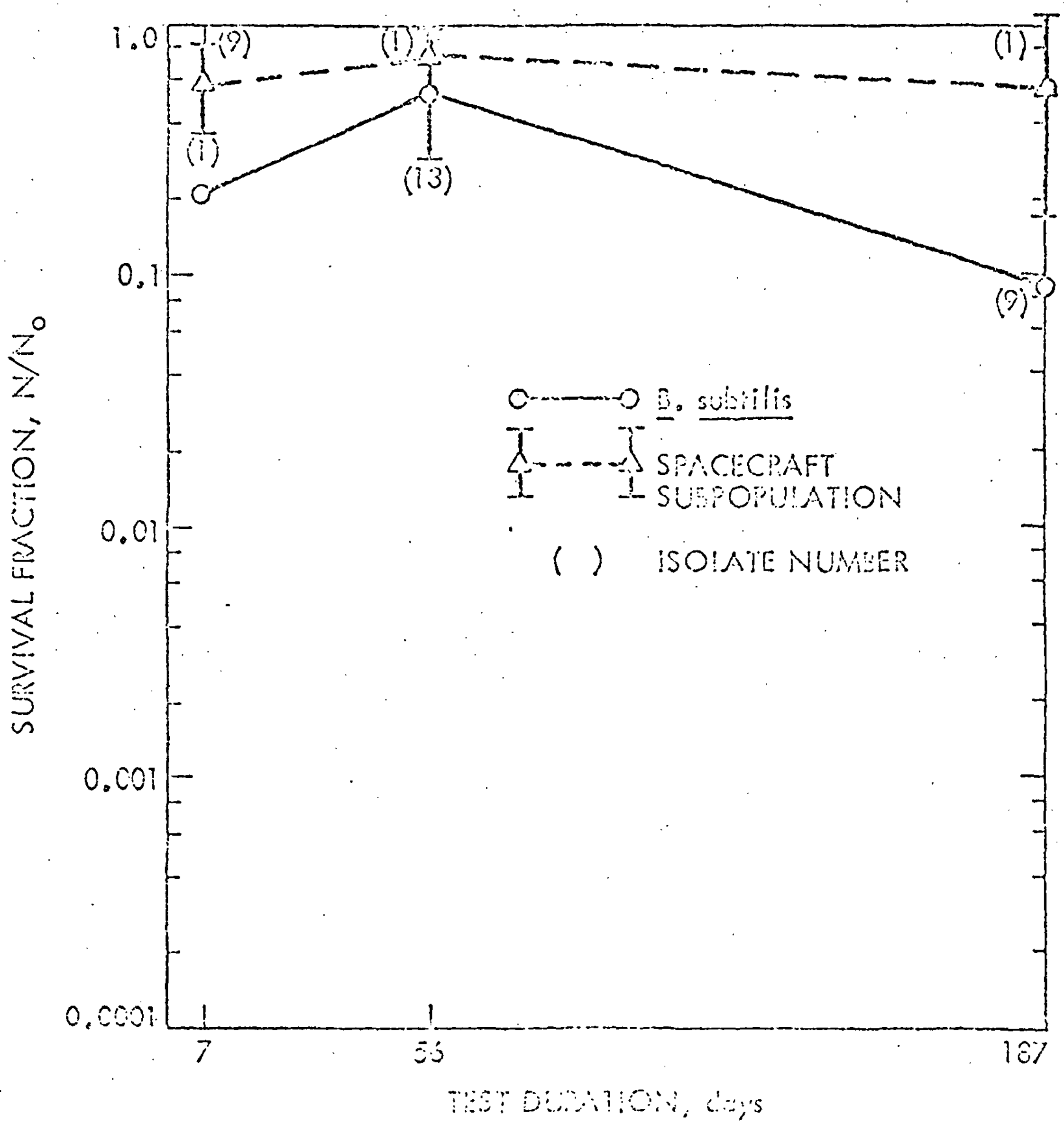
EFFECT OF VACUUM AND TEMPERATURE (-40°C) ON SPACECRAFT ISOLATES



PQAP
New Orleans
Feb.1,1973

Figure 3.1-6

EFFECT OF VACUUM AND TEMPERATURE (25°C) ON SPACECRAFT ISOLATES



PQAP
New Orleans
Feb.1,1973

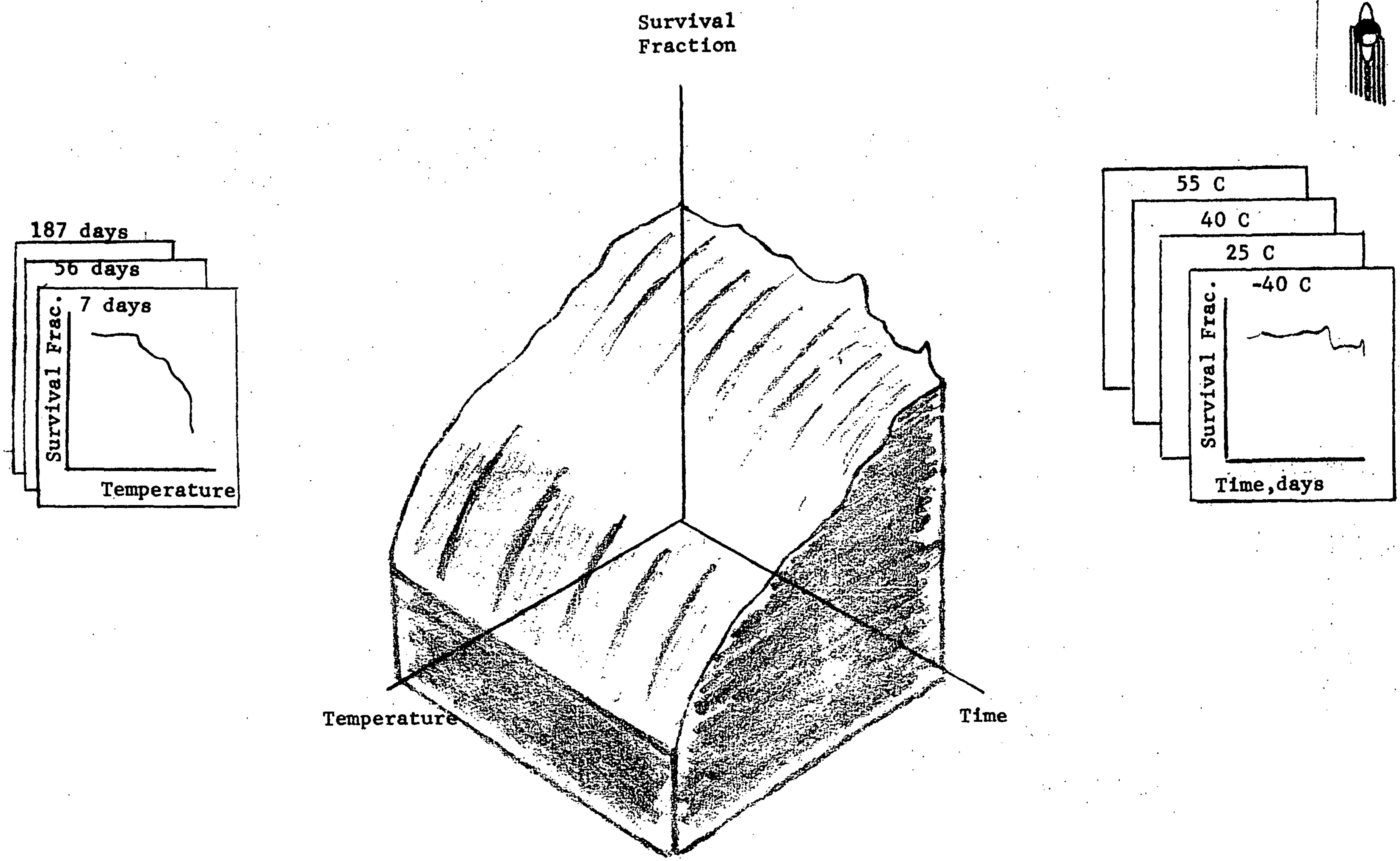


Figure 3.1-7

METHODS OF DATA PRESENTATION

P.I. Imshenetsky

Ref. No. 581

Organism: [ ] Spore [X] Vegetative Name see below

Temperature -23^{o}C

Duration 3 days

Surviving Fraction see below

Vacuum 10^{-9} mm Hg

Name	Surviving Fraction
Sarcina flava	.305
Mycobacterium rubrum	.302
Pseudomonas pyocyanea	.0034
Escherichia coli	.047
Pseudomonas fluorescens	0
Serratia marcescens	0
Vibrio metchnikouii	0

Figure 3.1-8

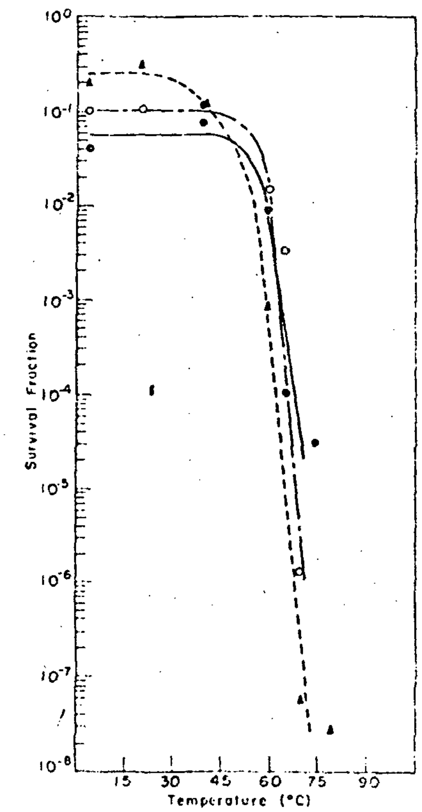


FIG. 2. *Survival of vegetative cells in ultrahigh vacuum (5 days) at various temperatures. Staphylococcus aureus,* ●; *Streptococcus faecalis,* ○; *and strain 248,* ▲. *Survival fraction equals the ratio of surviving cells over the original cell population after 5 days of storage over silica gel (20 C).*

Figure 3.1-9

Silverman & Beecher, 1966

Figure 3.1-10

DATA COMPARISON--SPORES, SHORT TIMES

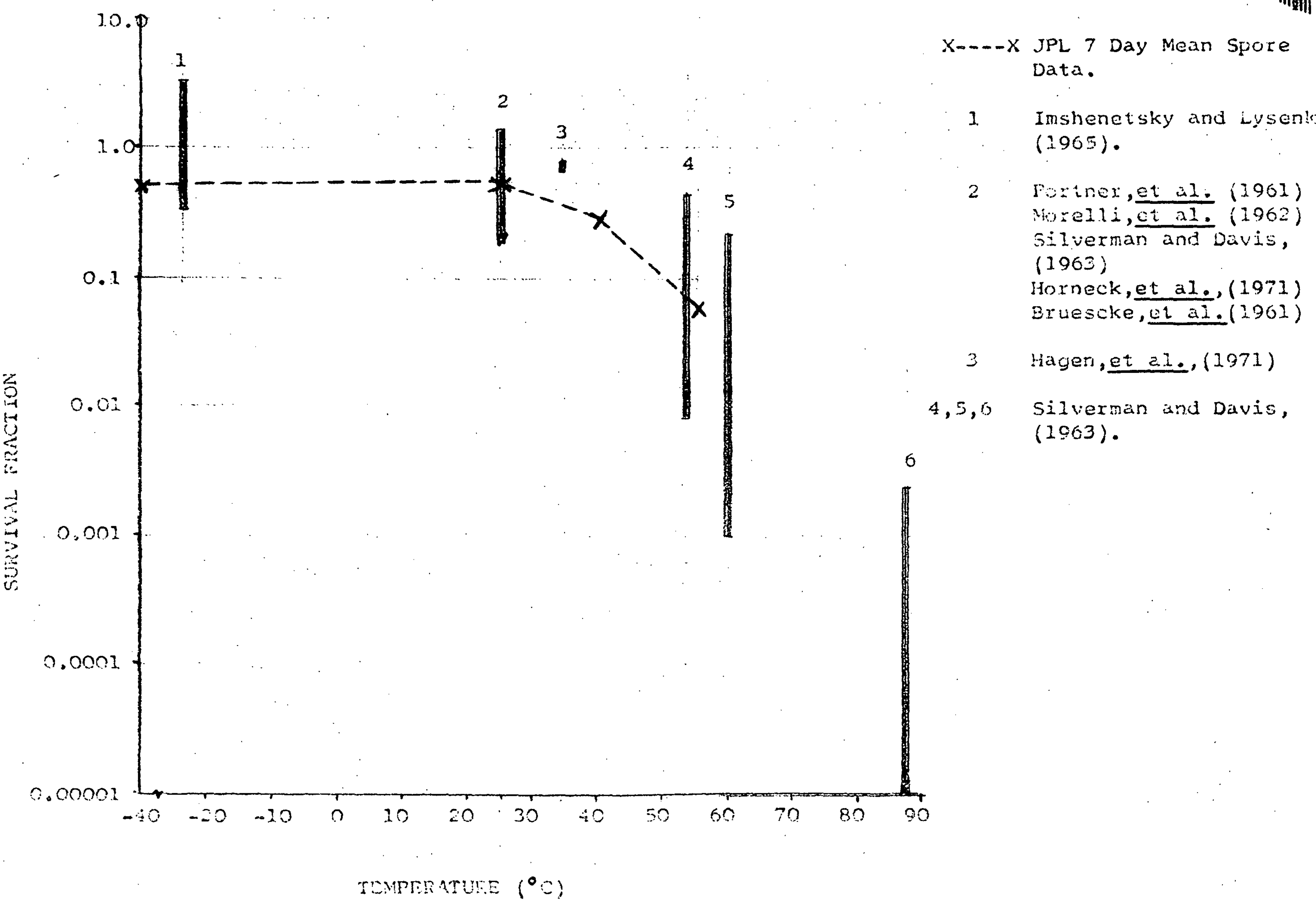
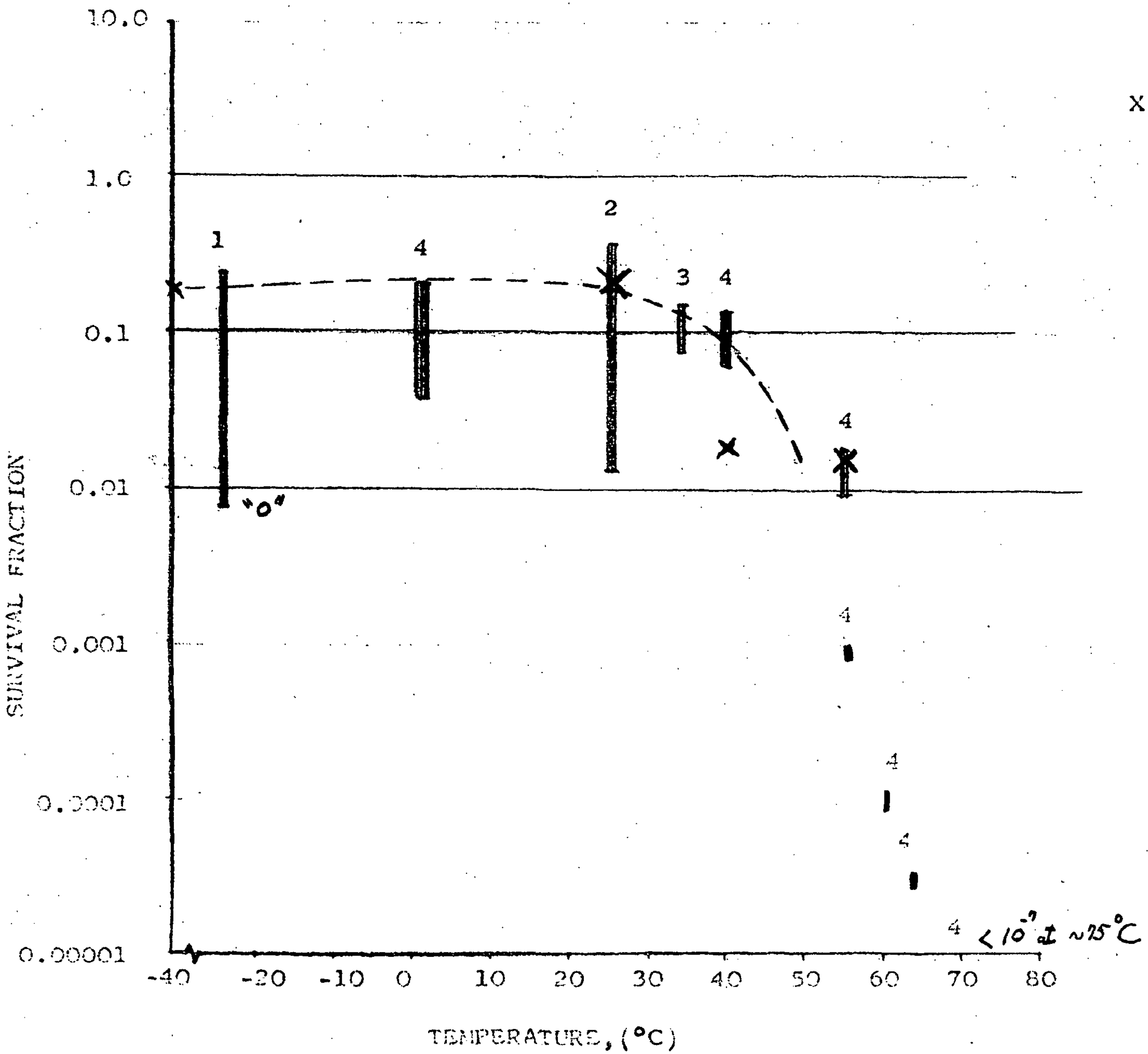


Figure 3.1-11

DATA COMPARISON--VEGETATIVE, SHORT TIMES



X----X JPL 7 Day Mean Vegetative Data.

1 Imshenetsky and Lysenko, (1965).

2 Portner, et al., (1961) Bucker and Horneck (1969) Silverman and Beecher, (1966).

3 Hagen, et al., (1971).

4 Silverman and Beecher, (1966).

Figure 3.1-12

Recapitulation & Approach to P(st) Definition

- Microbial Survival in space is definite function of Time & Temperature.
- Functional relationship reasonably well defined over certain regions.
- Approach to P(st) definition:
  - should utilize experimental data.
  - should not require new bioassay procedures.
  - should be conservative in poorly defined time/temperature regions.

P(st)

PARAMETER TITLE: *Probability of Surviving Space Travel*

VALUE	
UPPER	1.0
ACCEPTABLE	See Curves Page 2
LOWER	.01

APPLICATION	
MISSION	ALL
PLANET	ALL

PARAMETER DEFINITION: The probability that a microorganism, exposed to the vacuum-temperature conditions of interplanetary space travel, will survive.

APPLICABLE SOURCE: Surface microbial populations, both spores and vegetative, which have not been exposed to heat sterilization or radiation decontamination.

CONSTRAINTS:

P(st) = 1.0 for any times less than 28 days

P(st) = 1.0 for any temperature less than 25°C

P(st) = value from curves shown on page 2

P(st) = 187 day value for longer exposure times, see page 2

Values may be extrapolated in the unshaded regions of page 2.

REFERENCES: Discussions of Recommendations Regarding Value of P(st). A IBS PCAP Meeting, Cape Kennedy, Florida, April 26-27, 1973.

Planetary Quarantine Officer

Date

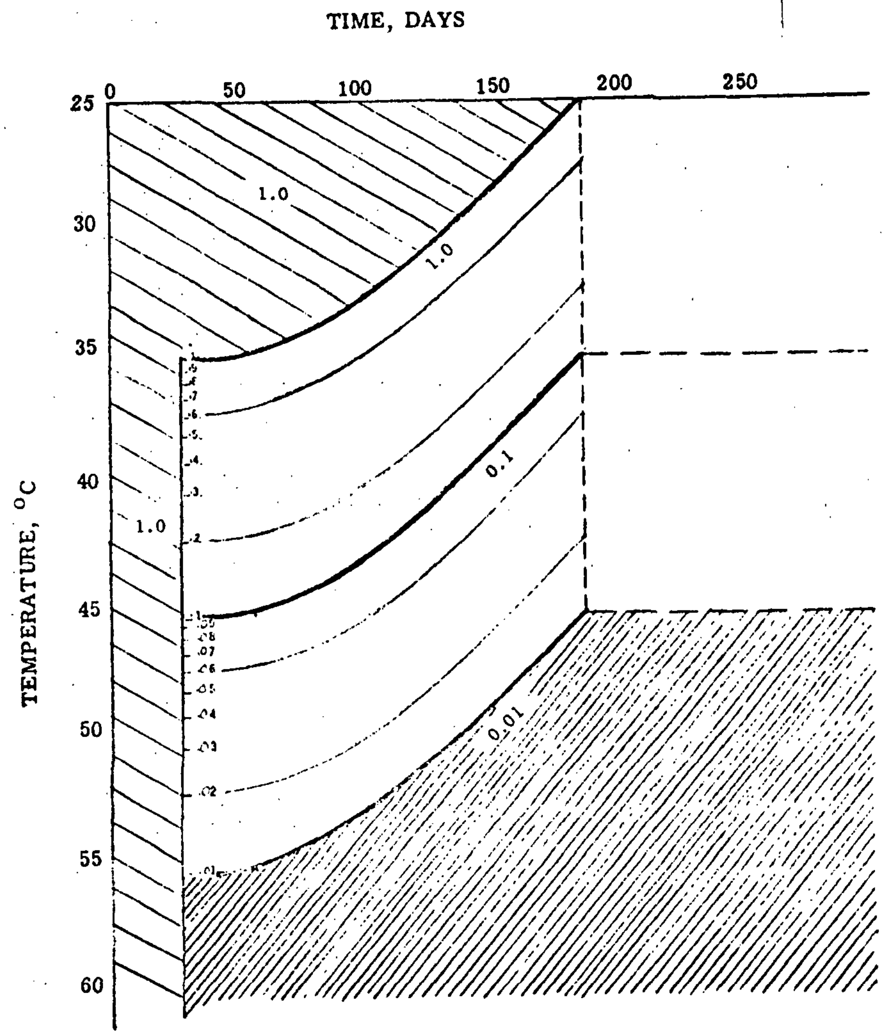


Figure 3.1-13. Proposed P(st) Parameter

3.2 Early Teflon Strip Experiment Analysis

Summary

At the request of the PQO, an analytical review of data from early teflon strip experiments, using wild organisms, was undertaken and the results and recommendations presented to PQP on April 26, 1973 at Cape Kennedy, Florida. This report summarizes results of this activity.

Discussion

Data resulting from teflon strip experiments conducted at JPL and Cape Kennedy with wild organisms were reviewed and analyzed in an effort to develop a valid methodology to identify the fraction of the surviving sub-population and its heat resistance.

The experiments at JPL were conducted at 125° C; the Cape experiments included tests at both 125° C and 113° C temperatures.

In the course of the analysis, it was recognized that the initial spore population consisted of several sub-populations of varying heat resistance. It became the purpose of the review to identify the most hardy sub-population.

The available data from JPL and the preliminary data from the Cape work were first treated similarly to arrive at an average initial spore population (N_o) and to estimate the most probable number (MPN) of survivors for each run. These data were then plotted versus heating time. In all instances the final two data points were used to derive D values.

The use of only the final two data points (instead of a "best fit" line through all data points) assures a D value representative of the most heat resistant sub-population. In addition, the last two data points are the most valid statistically since the error associated with their determination through the MPN technique is minimal when compared with earlier data points having relatively high MPN's.

Following this procedure, D values were established for the most heat resistant sub-populations and, through extrapolation, an N_o corresponding to that sub-population was derived. Through this procedure, shown in the following graphs and summary tables, the fraction of the initial spore load representing the most resistant sub-population was obtained.

It is significant to note the consistency observed in all of the data, and the fact that it appears from these results that the Z value of 21°C holds for the wild organisms. It is recognized, however, that the analysis is based on preliminary and, in the case of 113°C experiments, incomplete data. Hence, recommendations were made for additional data particularly in the region where the fraction of survivors is low.

A further recommendation relates to the characterization of survivors which, it is felt, should be taken into account in any reevaluation of P(g).

The following figures, descriptive of the above analysis, were presented to PQP at Cape Kennedy on April 26, 1973.

PURPOSE

- ESTABLISH COMMON FRAMEWORK FOR EXAMINING THE DATA
- IDENTIFY HEAT RESISTANCE OF THE HARDY SUBPOPULATION
- IDENTIFY THE FRACTION OF THE HARDY SUBPOPULATION TO TOTAL SPORE POPULATION

Figure 3.2-1

- APPROACH
- USPHS 125 C DATA
- JPL — WARDLE 125 C DATA
- USPHS EARLY 113 C DATA
- SUMMARY
- CONCLUSIONS
- RECOMMENDATIONS

Figure 3.2-2

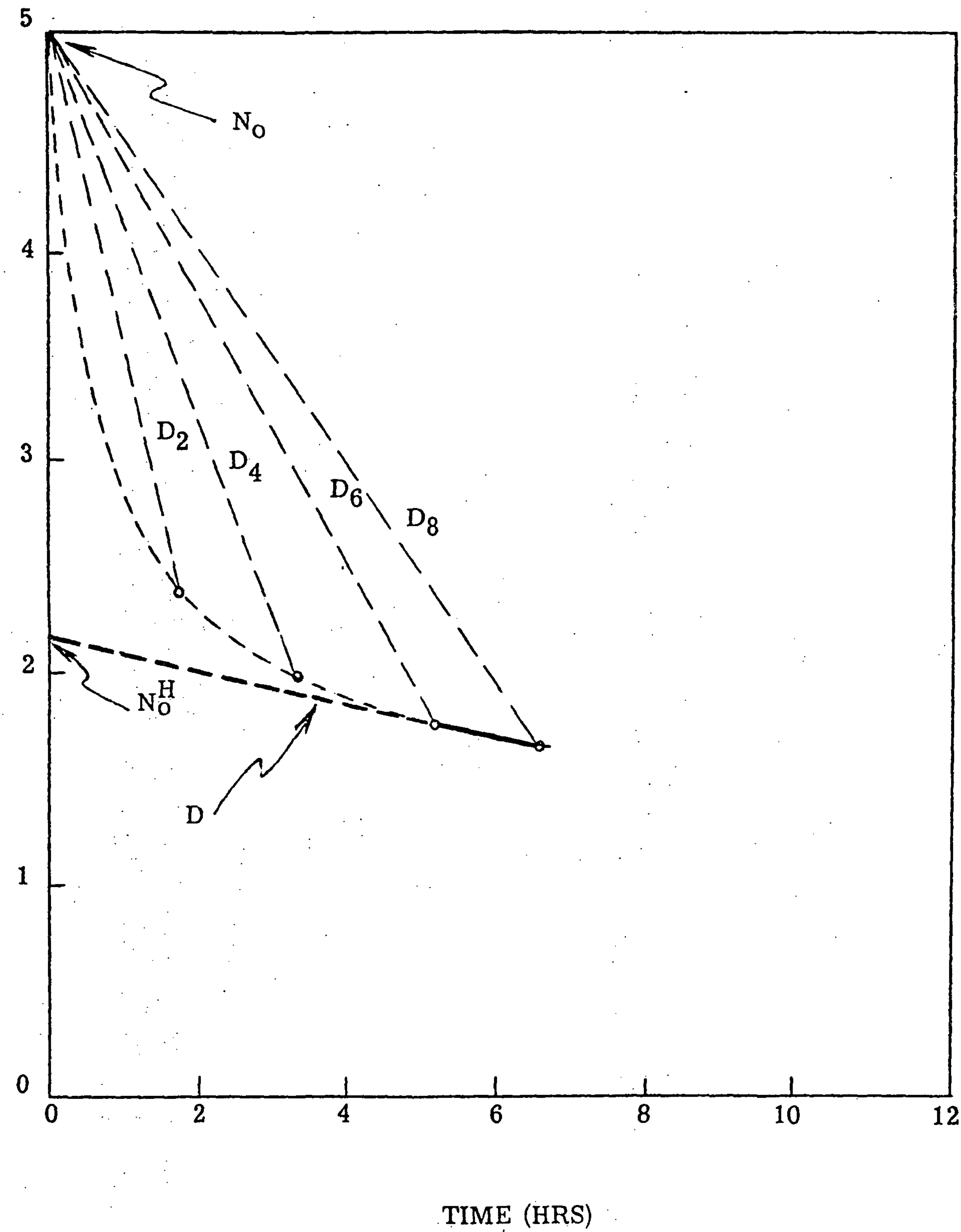


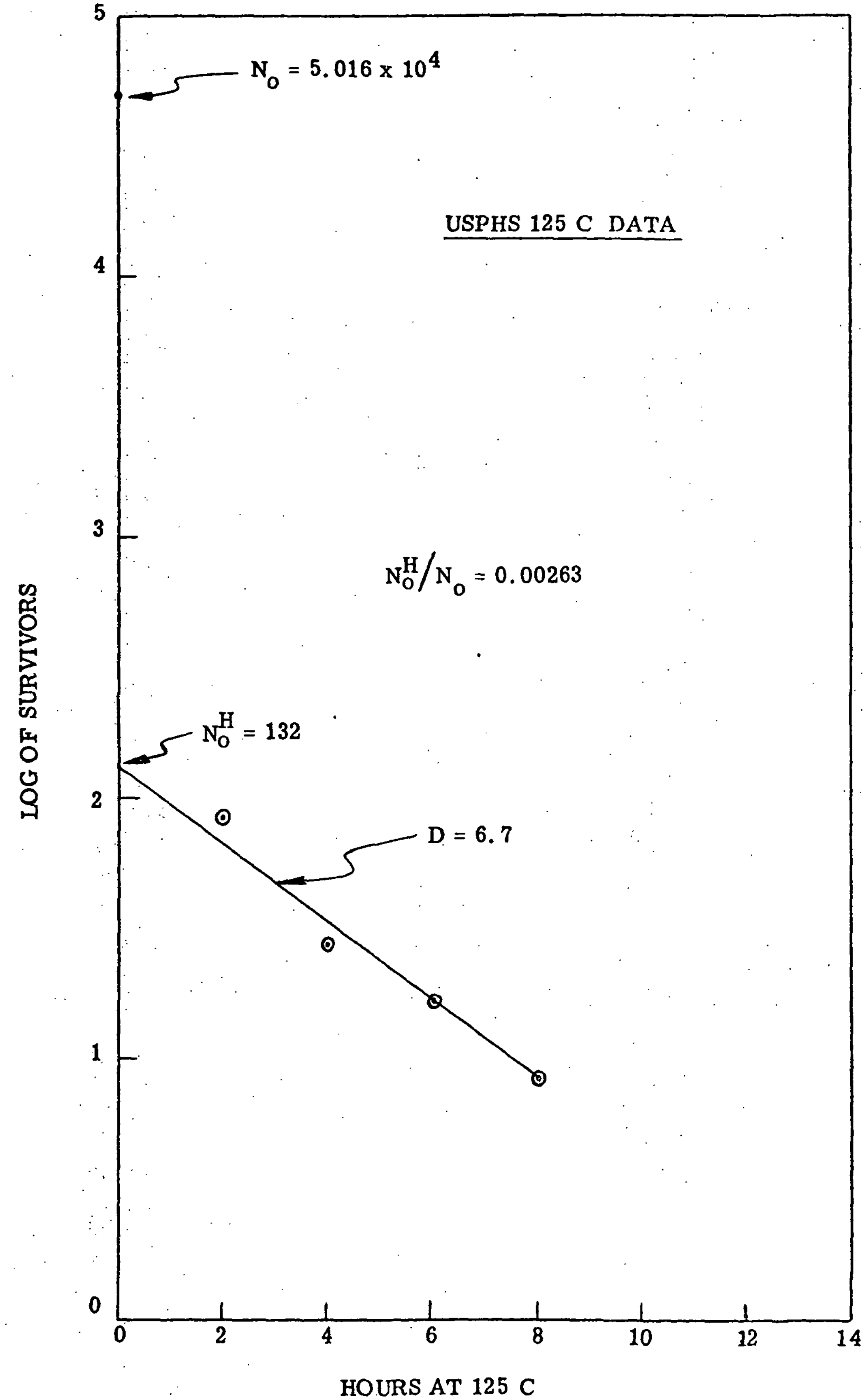
Figure 3.2-3
LOG OF SURVIVORS

Figure 3.2-4

USPHS 125 C DATA

Heating Time (HRS)	No. of Strips	Spores/Strip	Surv./Strip	Fraction of Positives	MPN/Strip	Total MPN	Average N_o	Total N_o
2	228	2.2×10^2	69/228	.303	.360	82	2.2×10^2	5.016×10^4
4	228	2.2×10^2	26/228	.114	.121	27.6	2.2×10^2	5.016×10^4
6	222	2.2×10^2	16/222	.072	.074	16.87	2.2×10^2	5.016×10^4
8	198	2.3×10^2	7/198	.035	.036	8.21	2.2×10^2	5.016×10^4
9	24	2.0×10^2	---	--	--	---	---	---

Figure 3.2-5



$N_o = 5.016 \times 10^4$
USPHS 125 C DATA
$N_O^H / N_o = 0.00263$
$N_O^H = 132$
D = 6.7
LOG OF SURVIVORS
HOURS AT 125 C
0
1
2
3
4
5
0
2
4
6
8
10
12
14

Figure 3.2-6

WARDLE'S 125 C DATA

Heating Time (HRS)	No. of Strips	Spores/Strip	Surv. /Strip	Fraction of Positives	MPN/Strip	Total MPN	Average N_o	Total N_o
1	12	5.86×10^2	10/12	0.83	1.79	63	8.65×10^2	2.07×10^4
3	24	1.29×10^3	12/24	0.50	0.693	11.16	8.65×10^2	2.07×10^4
6	23	9.56×10^2	5/23	0.217	0.247	5.35	8.65×10^2	2.07×10^4
9	19	6.29×10^2	1/19	0.0526	0.053	1.75	8.65×10^2	2.07×10^4
13	42	8.33×10^2	0/42	--	--	--	---	---

Figure 3.2-7

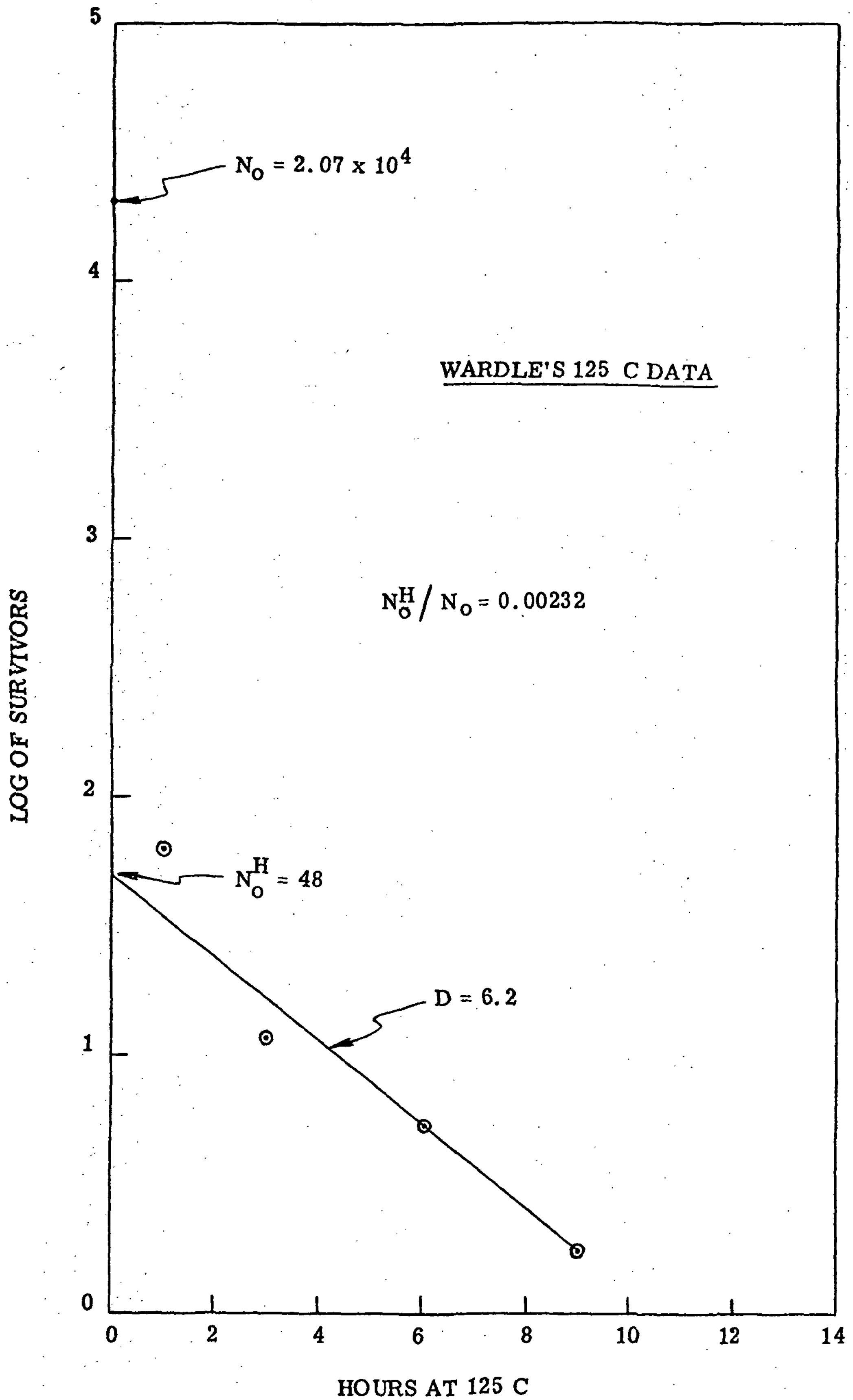

5
4
3
2
1
0
LOG OF SURVIVORS
$N_o = 2.07 \times 10^4$
WARDLE'S 125 C DATA
$N_o^H / N_o = 0.00232$
$N_o^H = 48$
D = 6.2
0
2
4
6
8
10
12
14
HOURS AT 125 C

Figure 3.2-8
USPHS 113 C DATA

Heating Time (HRS)	No. of Strips	Spores/Strip	Surv./Strip	Fraction of Positives	MPN/Strip	Total MPN	Average N_o	Total N_o
6	36	3.3×10^2	33/36	.917	2.485	89.46	2.85×10^2	1.026×10^4
12	36	2.6×10^2	19/36	.528	0.750	27	2.85×10^2	1.026×10^4
18	36	3.1×10^2	8/36	.222	0.250	9	2.85×10^2	1.026×10^4
24	36	2.4×10^2	5/36	.139	0.149	5.36	2.85×10^2	1.026×10^4

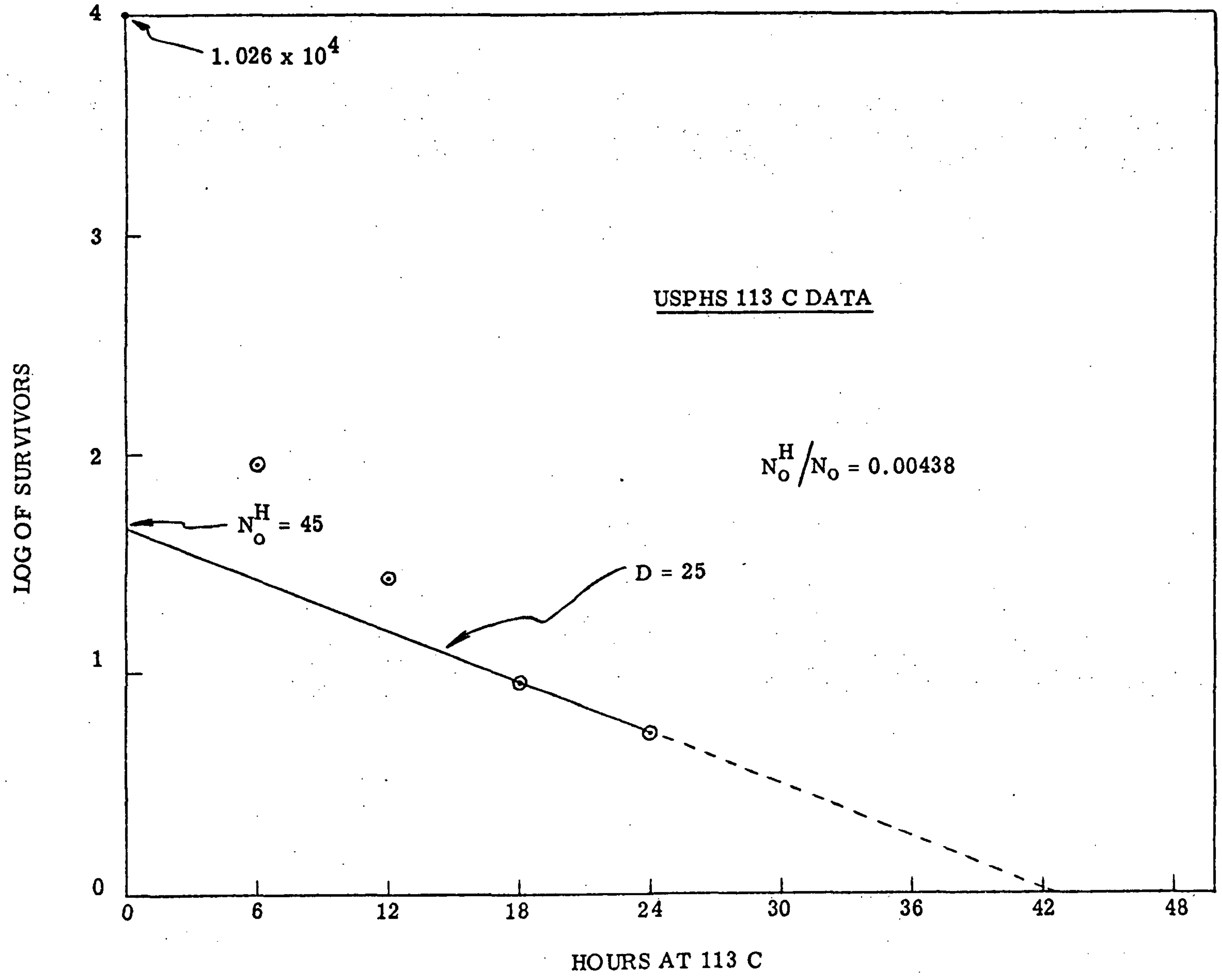
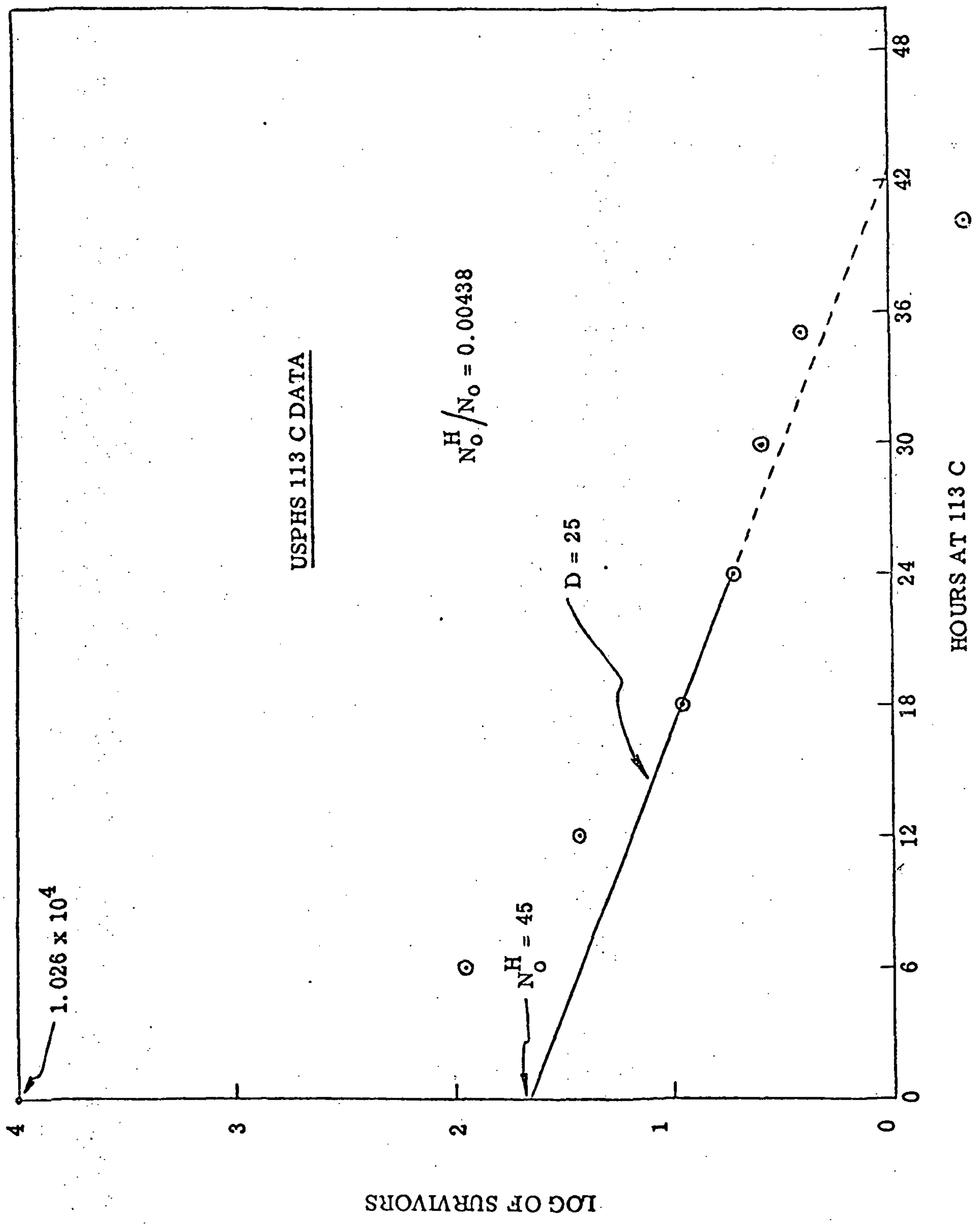

USPHS 113 C DATA
1.026 x 10^4
N_o^H = 45
N_o^H/N_o = 0.00438
D = 25
LOG OF SURVIVORS
HOURS AT 113 C
0
1
2
3
4
0
6
12
18
24
30
36
42
48

Figure 3.2 - 9

Experimenter / ITEM	WARDLE (125 C)	USPHS (125 C)	USPHS (113 C)	USPHS (113 C) EXTRAP. TO (125 C)
N_o TOTAL	2.07×10^4	5.016×10^4	1.026×10^4	
N_o^{Hardy}	48	132	45	
FRACTION OF HARDY	.00232	.00263	.00438	
D_{Hardy} (Hours)	6.2	6.7	25.0	6.7

Figure 3.2 - 10

Figure 3.2 - 11



USPHS 113 C DATA
$N_o^H / N_o = 0.00438$
D = 25
$N_o^H = 45$
1.026×10^4
HOURS AT 113 C
0
6
12
18
24
30
36
42
48
LOG OF SURVIVORS
0
1
2
3
4

CONCLUSIONS

- A METHODOLOGY HAS BEEN ESTABLISHED TO IDENTIFY THE FRACTION OF THE HARDY SUB-POPULATION AND ITS HEAT RESISTANCE.

- APPLYING THIS METHODOLOGY, THE DATA ANALYZED APPEARS TO BE CONSISTENT.

Figure 3.2 - 12

RECOMMENDATIONS

- ANY ADDITIONAL DATA SHOULD BE OBTAINED IN THE REGION WHERE THE FRACTION OF CONTAMINATED REPLICATES IS LOW (i.e. < 0.1)
- USING THIS METHODOLOGY AND ANY ADDED DATA, THERE SHOULD BE AN EVALUATION OF THE MANNER IN WHICH THE DATA CAN BE USED TO ASSESS STERILIZATION CYCLES BY FLIGHT PROJECTS
- TO THE EXTENT THE HEAT CYCLE IS BASED ON A RESIDUAL NUMBER OF HARDY ORGANISMS, ANY REEVALUATION OF THE PROBABILITY OF GROWTH, P(g), SHOULD TAKE THIS INTO ACCOUNT

Figure 3.2 - 13